Residual Stress Mapping of Engine Blocks

Background

An engine casting plant identified the development of residual stresses in their cast aluminum engine blocks to be due to differential cooling during processing. Concern for the presence of these stresses derives from the distortion of critical features during machining, which increases the difficulty of maintaining dimensional tolerances, particularly for the main web area. In an effort to remove these residual stresses, the engine blocks are subjected to a T5 stress relief treatment prior to machining. The stress relief treatment has added complexity to the process, and the stress relief oven has become a major production volume-limiting step. Alternate stress relief cycles, capable of allowing greater throughput in the stress relief oven, would be beneficial in this regard. The engine casting plant consulted researchers from Ohio State University to help with this problem. To understand the problem better, these researchers went to the High Temperature Materials Laboratory (HTML) at Oak Ridge National Laboratory (ORNL) to map the residual strains/stresses in a series of heat treated engine blocks using X-ray and neutron diffraction.

The Technology

Diffraction is used to probe the crystal structure of materials. Specifically, the spacing between planes of atoms can be measured. Applied or residual forces pull or squeeze the crystal structure, changing the spacing of

Engine block mounted and ready for stress mapping with X-ray gantry system

Benefits

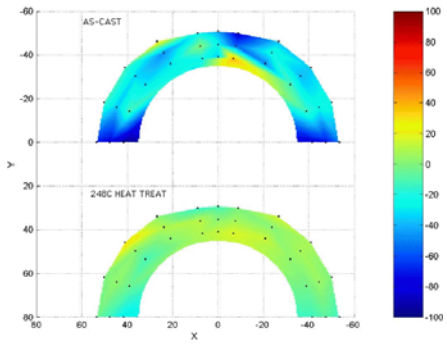
- Ohio State University researchers were able to access the extensive state-of-the-art materials characterization capabilities at the HTML to address a specific industrial concern.
- Greater understanding of residual stress and strain, and the effects of heat treatment on relieving residual stress/strain.

these planes. This change can be measured and converted into a residual stress. Diffraction can be accomplished with X-rays and neutrons, which provide information from the surface and bulk of a material, respectively.

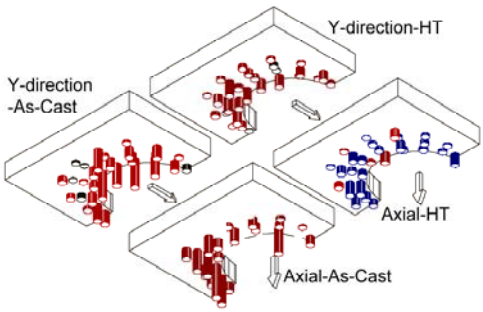
Residual stresses in as-cast and annealed aluminum engine blocks were mapped in the main web area above the bearing split using diffraction. Using X-rays, computer controlled coordinate-mapping of the radial and hoop strains was performed. The X-ray system consists of a portable X-ray stress analyzer mounted overhead to a gantry which forms the frame for a 15 × 8.2 × 9.2 ft (length × width × height) shielded enclosure (see figure on page 1). This setup can accommodate small and large samples up to 250 pounds.

Neutron strain mapping was performed using the Neutron Residual Stress Facility within the HTML, but located at the High Flux Isotope Reactor. A new double-focusing silicon monochromator was employed to deliver a high flux of neutrons to the sample. Using neutrons, computer controlled coordinate-mapping of the axial and Y direction strains.

The heat treatments were effective in reducing the overall residual stresses in the main web area above the bearing split. The surface stresses went from compressive to near zero or slightly tensile with increasing heat treatment temperature. In concert, the bulk strains went from tensile to slightly tensile or compressive with increasing heat treatment temperature. Given the complex geometry of the engine block, complete stress relief may not be realistic given asymmetric constraints of the engine block structure.



Hoop stresses in the as-cast and 248C heat treated engine blocks using X-rays



Axial and Y-direction strains in the as-cast and 230C heat treated engine blocks using neutrons

Where Can I Find More Information?

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